Wind Visualization at Xcel Energy

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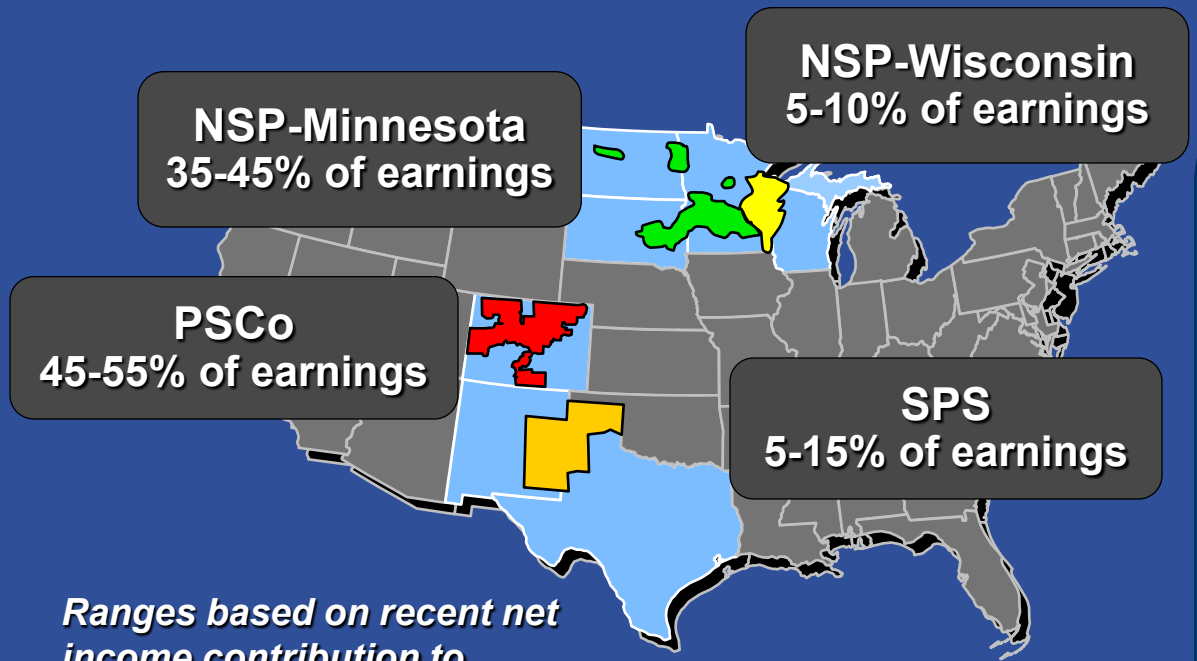
Program

- Background on Xcel Energy
- Introduce Power Operations & Trading at Xcel Energy
- Examine corporate wide wind forecasting system
- Explore several decision support tools and displays
  - Northern States Power (NSP) –MISO Market
  - Southwestern Public Service (SPS) – SPP Market
  - Public Service Colorado (PSCo)

Company Profile



Ranges based on recent net income contribution to consolidated earnings

2012 Annualized Dividend = $1.08 per share

2012 EPS Guidance = $1.75 - $1.85* per share

*Forecasted to be in the lower half of the range

Fully Regulated

Operate in 8 States

Combination Utility
Electric 89% of cont. ops
Gas 11% of cont. ops

Customers
3.4 million electric
1.9 million gas

2011 Financial Statistics
Net Income: $841 million
EPS: $1.72
Annualized dividend: $1.04
Assets: $29.5 billion
Equity ratio: 46%

Responsibilities

- **All four Xcel operating companies are managed in Denver on our trading floor**
  - System reliability/safety is our number one responsibility
  - Least cost generation dispatch solution
  - Wholesale markets

Power Operations

- System Reliability
- Plant outage coordination
- Balance load and generation
- Least cost dispatch of resources
- Customer load, wind production, and fuel burn forecasting
- Market buy/sell signals
- Communication with centralized markets
- Demand side management activation
- Daily post analysis
- Generation modeling
- Reporting to regulators and centralized markets

Energy Trading

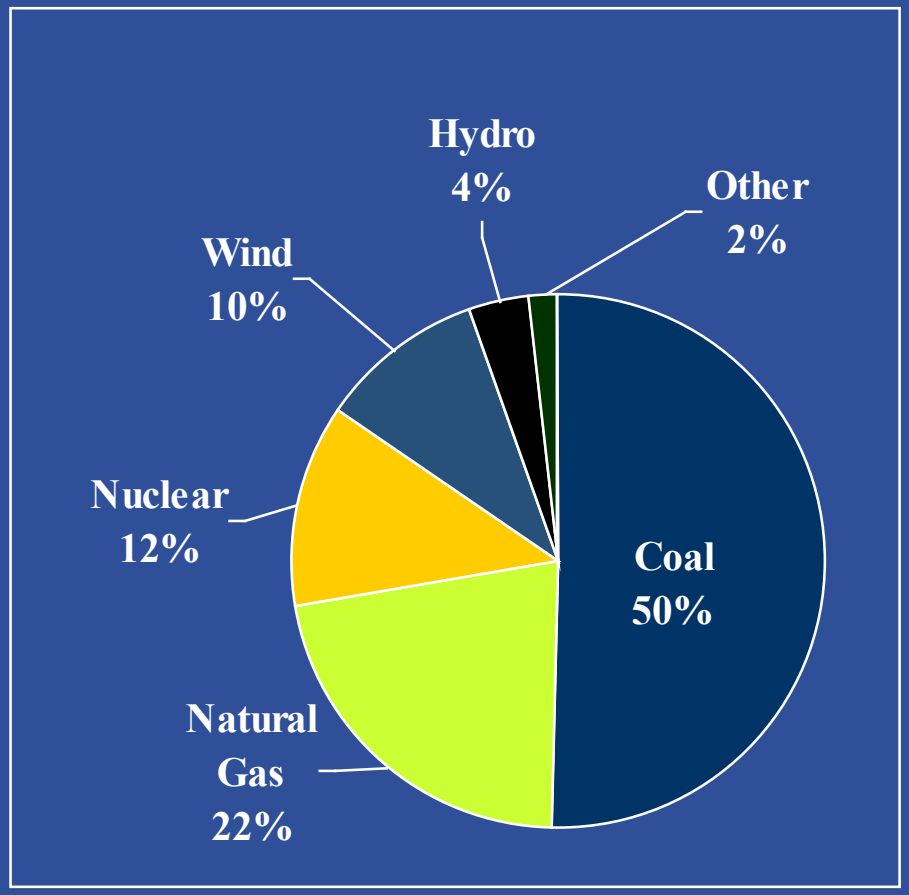
- Make electric purchases below our internal cost of generation
- Make electric sales when we have surplus generation resources
  - 90% of the profits are returned to customers in Colorado
- Develop and execute both short and long term electric and natural gas hedging strategies
- Manage renewable energy credits (RECs), emissions allowances

Optimization Inputs for Models Used Across Commercial Operations

- Load Forecast
- Unit Characteristics
  - Performance Monitoring Program
- Fuel
  - Mix of short and long term pricing
- Wind Forecast
  - Largest source of uncertainty
  - As Xcel integrates more wind, operational impacts increase

Xcel Power Supply Mix

Energy by fuel source, during 2011



- **Total Wind Energy at Xcel 10%**

  Energy Source by Operating Company during 2011:

  - **NSP – 10%**
  - **PSCo – 13%**
  - **SPS -- 8%**

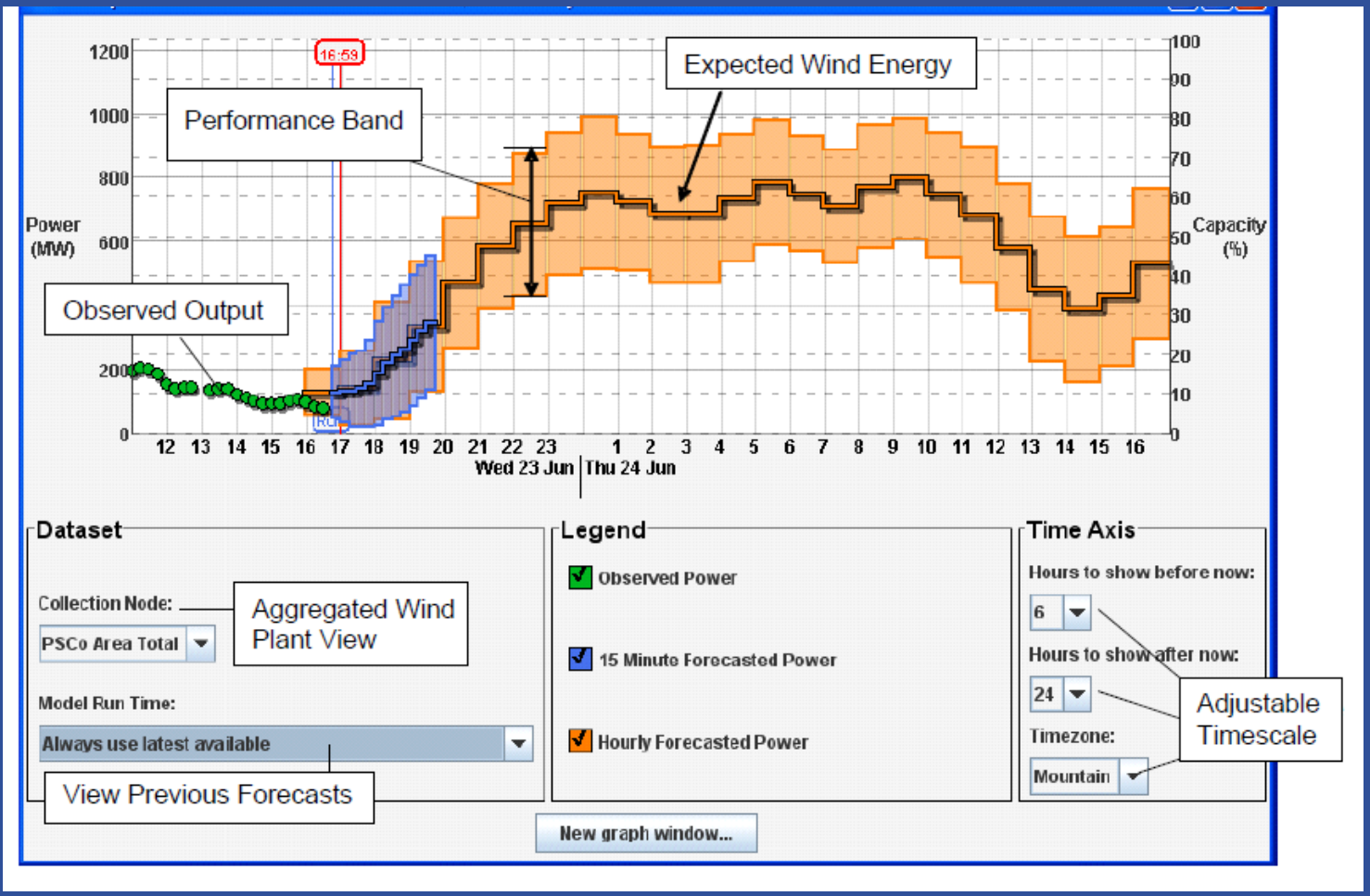
- **Xcel is adding nearly 1,000 MW wind capacity during 2012**
- **Xcel will have 5,000 MW wind capacity by end of 2012**

http://www.xcelenergy.com/xe-en/About_Us/Our_Company/Power_Generation/Power_Generation_Main

Wind Forecasting Improvements

- National Center for Atmospheric Research (NCAR) wind model implemented late 2009 and early 2010
  - 28% reduction in forecast error across the Xcel operating systems
  - $7 million/year in dispatch savings
- NCAR system inputs
  - Meteorological data
    - Recently added European weather model
  - Turbine-level data
  - Staff meteorologist insight
    - Icing, planned turbine maintenance, transmission outages
- NCAR system output
  - .csv files containing 15 minute and 1 hour forecasts
  - Graphical interface extensively used by real time operators
  - Weather-related snapshots for the staff meteorologists

NCAR Graphical Interface



Wind Visualization Tools and Displays

- Pi Process Book, a graphical interface to the OSIsoft PI System
  - Dynamic and interactive displays
- EMS Customization
- Excel
  - Interface with Pi System using Pi DataLink
    - Decision support tools
    - Ad hoc analysis

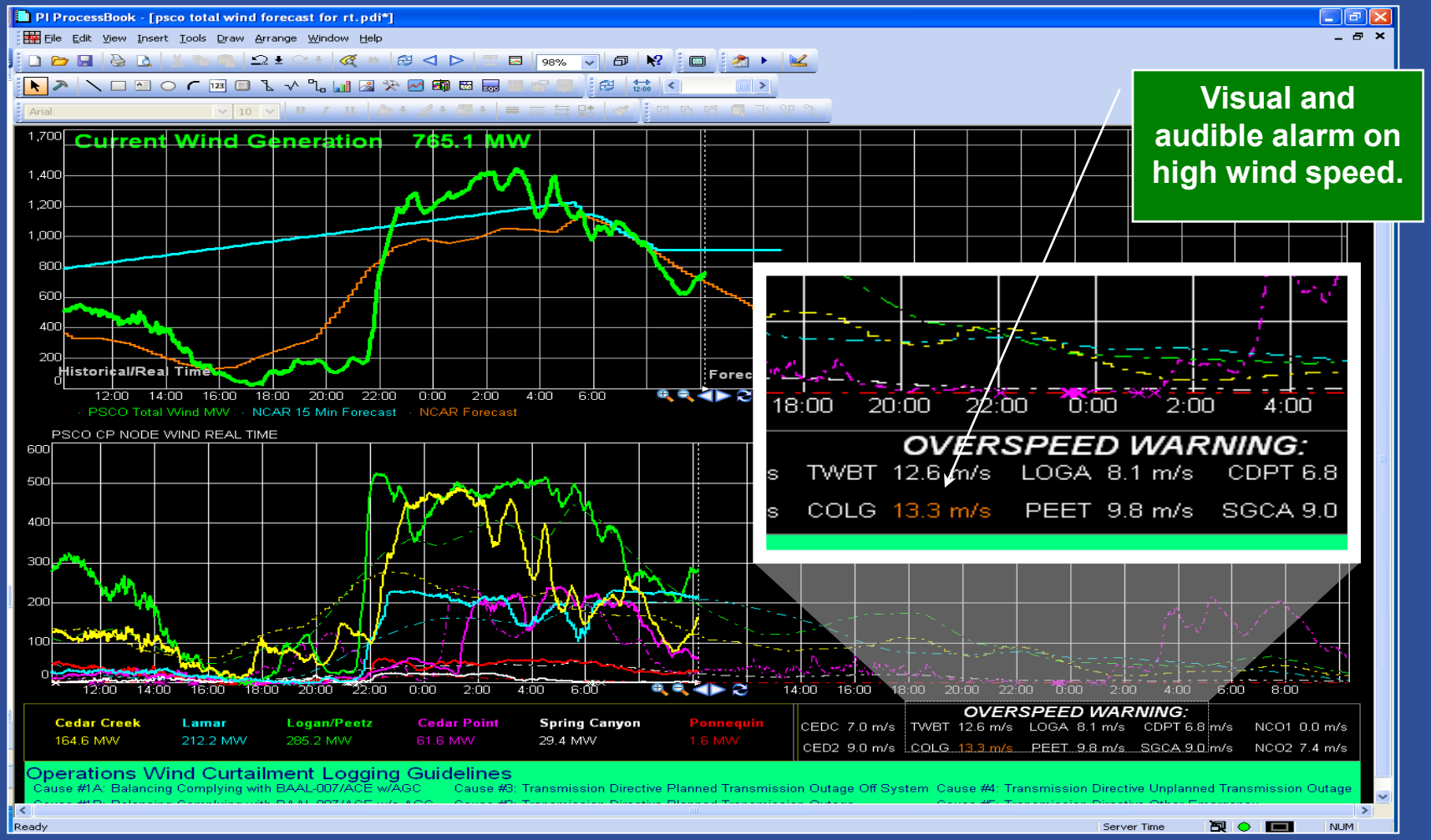
Display Needs Vary by Operating Company

- Wind Forecasting system (NCAR) is used across all three systems
- However each operating company has unique challenges with wind integration
  - Dissimilar regulatory frameworks
  - Operating in different markets
  - Dissimilar geographical areas
- Customized tools and displays required

PSCo –Wind Overspeed Issues

- At very high wind speeds most wind turbines cease power generation and shut down.
  - Display to warn operator of overspeed conditions
    - Operator recognizes when cut-outs may occur
    - Prepare to commit offline unit or manually dispatch other units in response
    - NCAR forecast is crucial in evaluation of whether to commit units

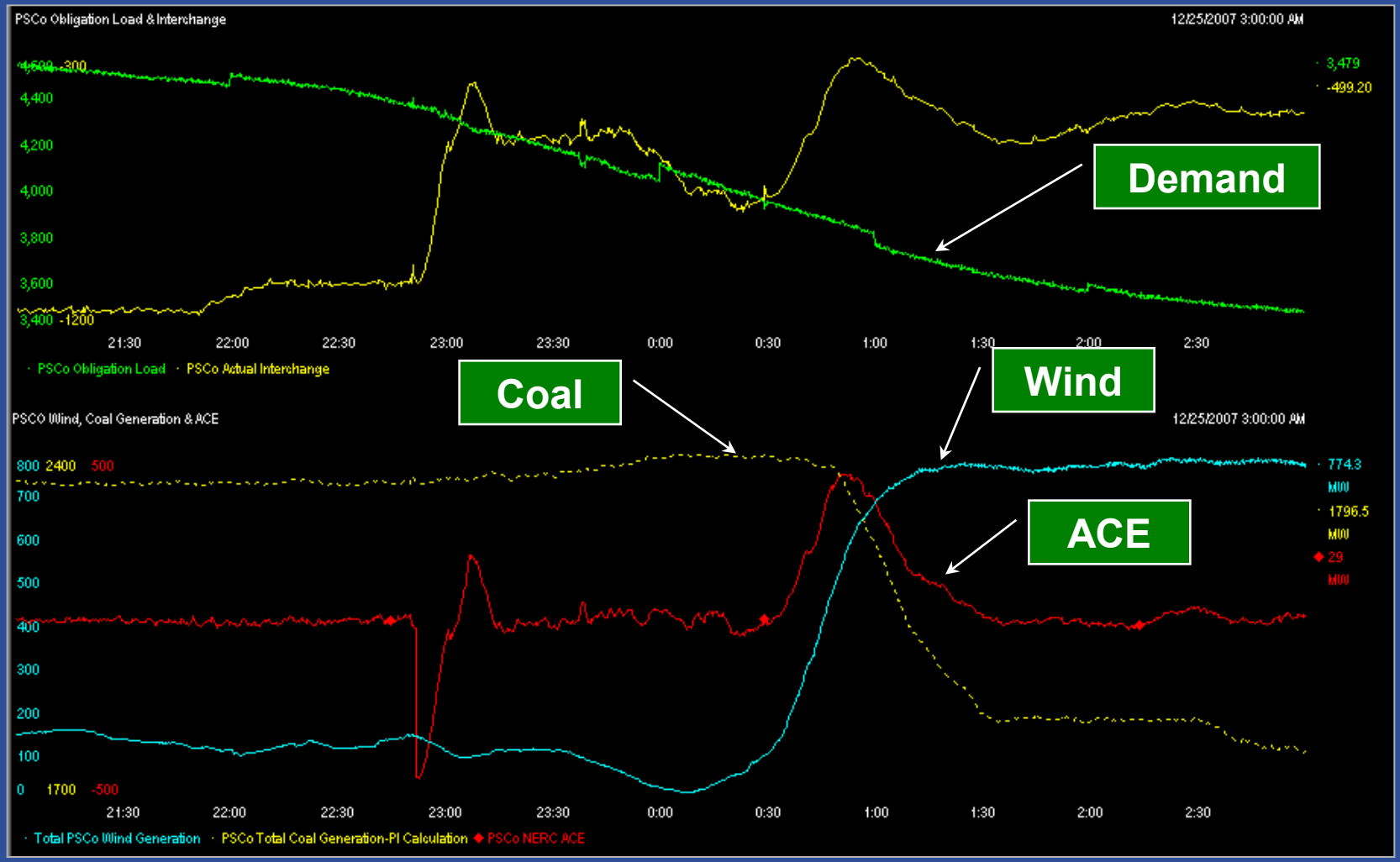
PSCo – Overspeed Warning Display



PSCo – Wind Ramp Events

- Strong Wind Ramps occur often in PSCo
  - Lack of geographic diversity among wind farms
- Reliability concern for PSCo
  - Lack of RTO/ISO to absorb wind ramps
    - Potential negative impact on the interconnection frequency and poor CPS scores
  - Displays to show operator ramping situation
    - Commitment or manual dispatch other resources
  - Lack of displays predicting ramping events

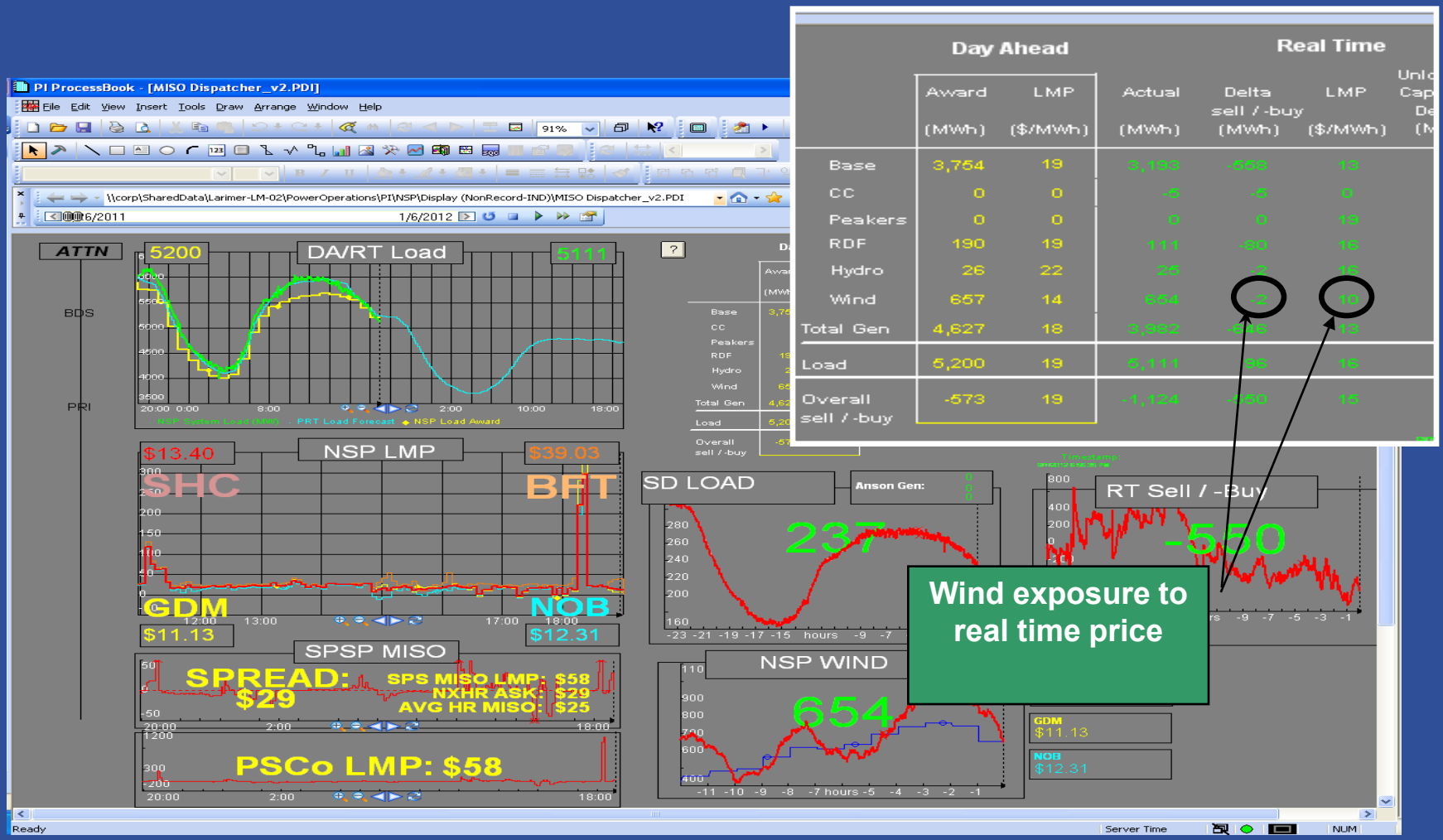
PSCo – ACE during Wind Push



Wind Challenges -- NSP Operating System

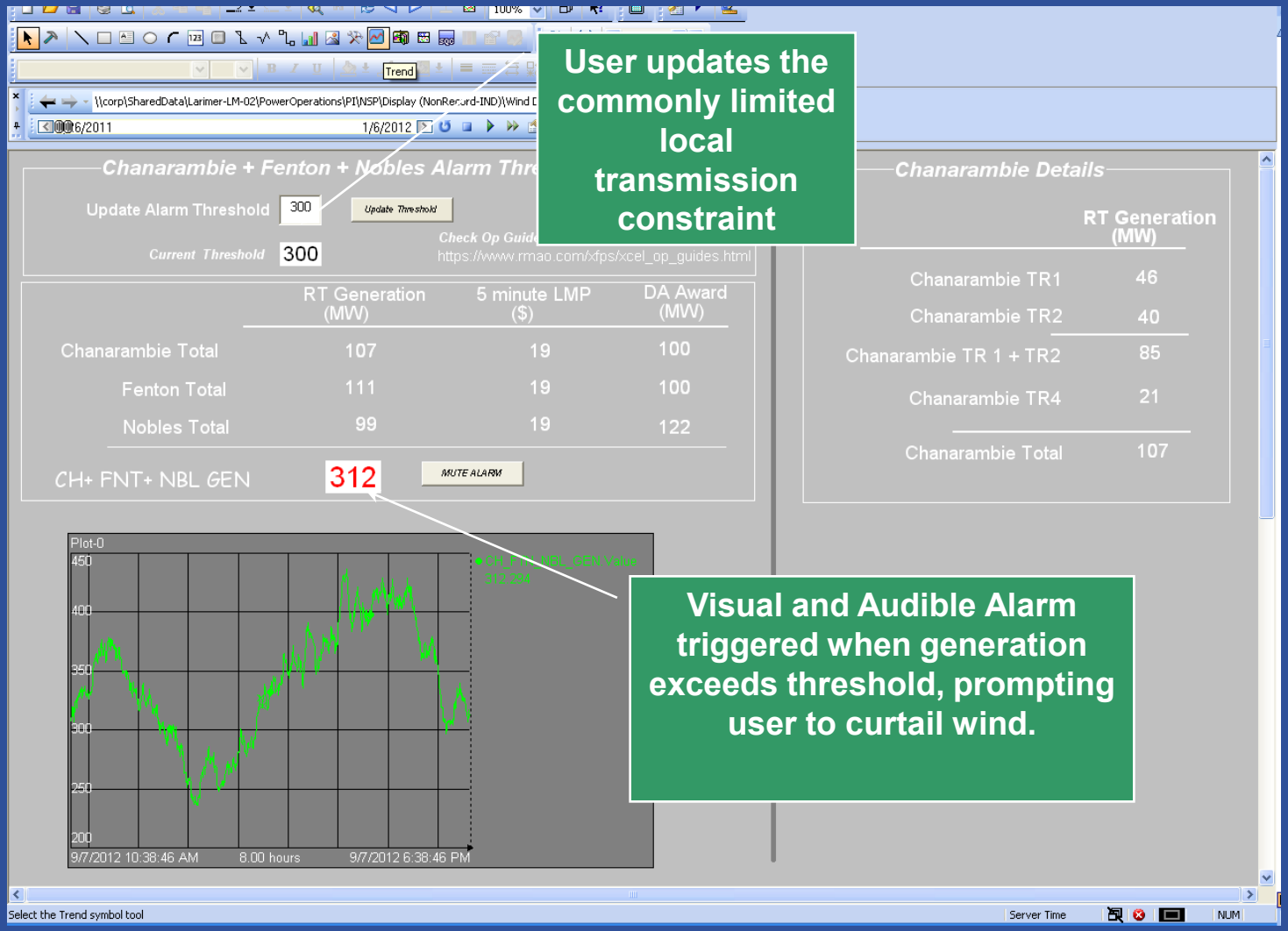
- NSP has fewer reliability concerns related to wind, relative to PSCo, due to NSP's participation in MISO market
    - Excess wind generation typically absorbed by market
- Nonetheless, wind management in NSP is a challenge
    - Managing wind around transmission constraints
    - Curtailments for economics during times of negative Locational Marginal Price (LMP)
- Understanding complexities of MISO charge types
    - Unexpected charges on Dispatchable Intermittent Resources (DIR) type units

NSP Display – at a glance summary

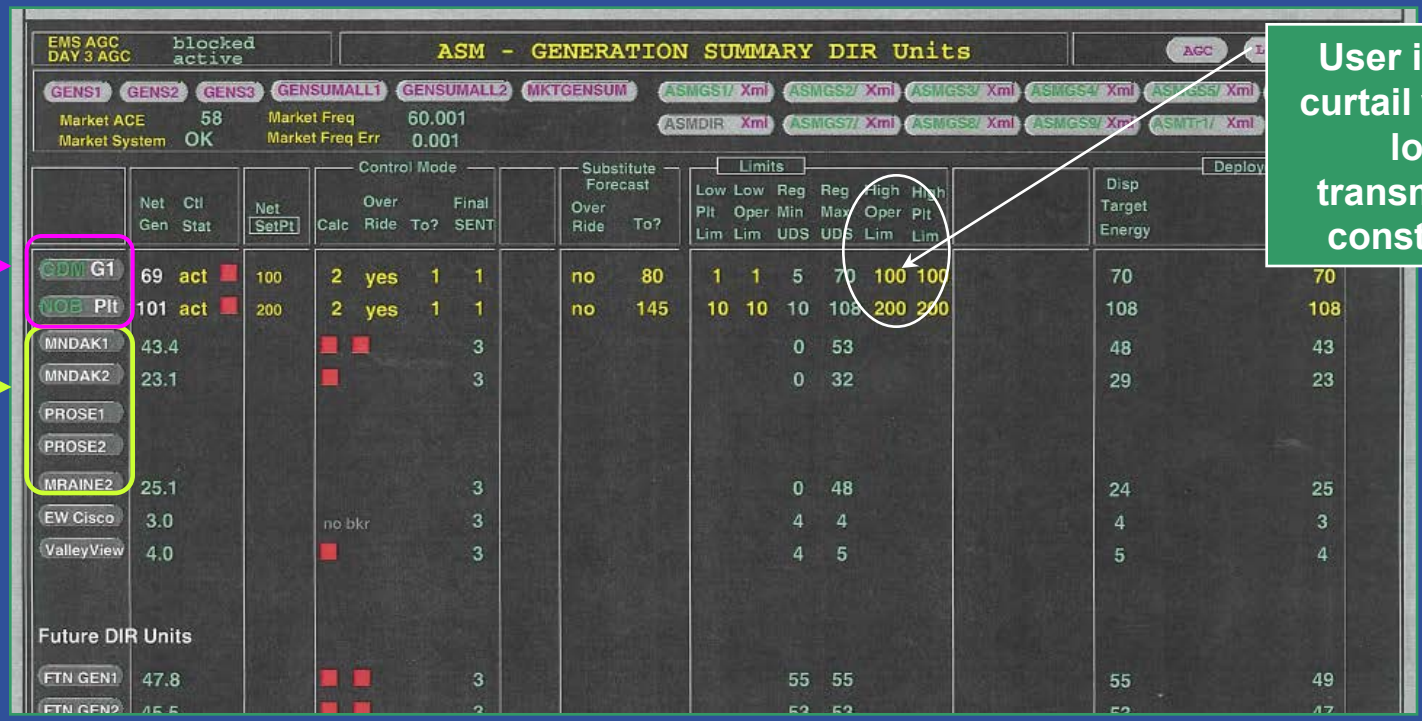


	Day Ahead			Real Time	
	Award (MWh)	LMP ($/MWh)	Actual (MWh)	Delta sell / -buy (MWh)	LMP ($/MWh)
Base	3,754	19	3,103	-650	19
CC	0	0	-5	-5	0
Peakers	0	0	0	0	19
RDF	190	19	111	-80	19
Hydro	26	22	25	-2	19
Wind	657	14	654	-2	19
Total Gen	4,627	18	3,892	-735	19
Load	5,200	19	5,111	-86	19
Overall sell / -buy	-573	19	-1,124	-550	19

NSP – Managing Wind for Transmission Constraints



NSP – Performing Wind Curtailments



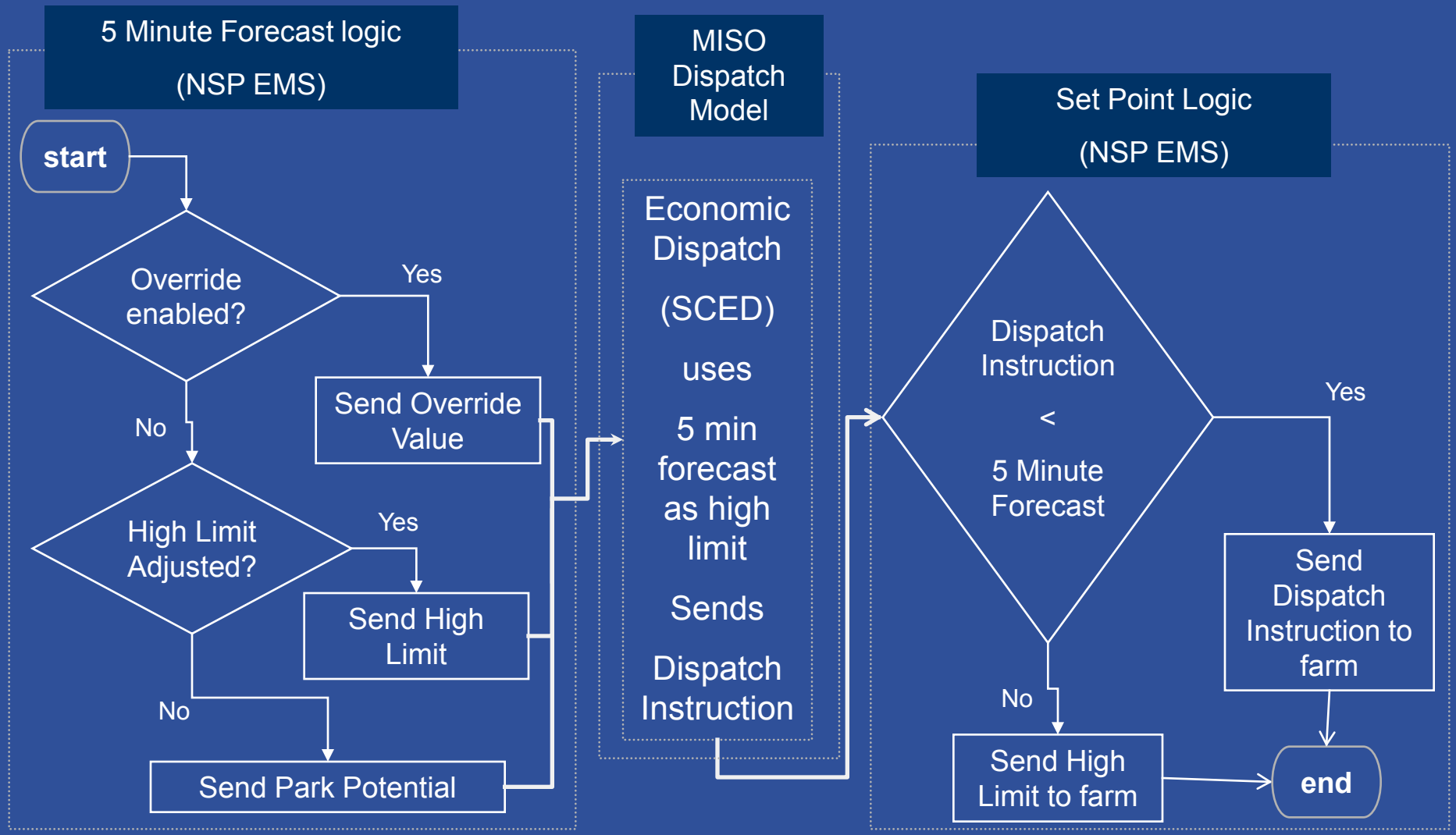
User input to curtail wind for local transmission constraints.

- Wind with set point control can be curtailed through EMS
- Wind without set point control requires manual curtailment via phone call
  - Ongoing projects for set point control where cost-justified

NSP - Dispatchable Intermittent Resources (DIR)

- MISO Created DIR unit type June 2011
- Wind must register as DIR type beginning March 2013
    - DIR units can participate in the real time energy market
    - Eligible for Day Ahead Revenue Sufficiency payments
- Set Point Control for DIR wind is ideal
    - Economic Curtailment is automatic based on value of wind output in the market
    - Requires EMS enhancements to support DIR set point control logic

NSP – Dataflow: Set Point Control Logic for DIR



NSP – Set Point Control Logic for DIR

- Current park potential sent to MISO as 5 minute forecast
- Operator can adjust 5 minute forecast via EMS DIR display
    - Override during ramping events
    - High limit adjustment for local transmission constraints
- MISO solves for economic dispatch, respecting the 5 minute forecast as the high operating limit
    - NSP EMS processes the dispatch instruction
        - Set point sent to the wind farm
            - If MISO dispatch instruction = 5 minute forecast
                - Send high operating limit as set point
                - Avoids unnecessary wind curtailments
            - If MISO dispatch instruction < 5 minute forecast
                - MISO is trying to dispatch unit down for economics
                - Send dispatch instruction value as set point

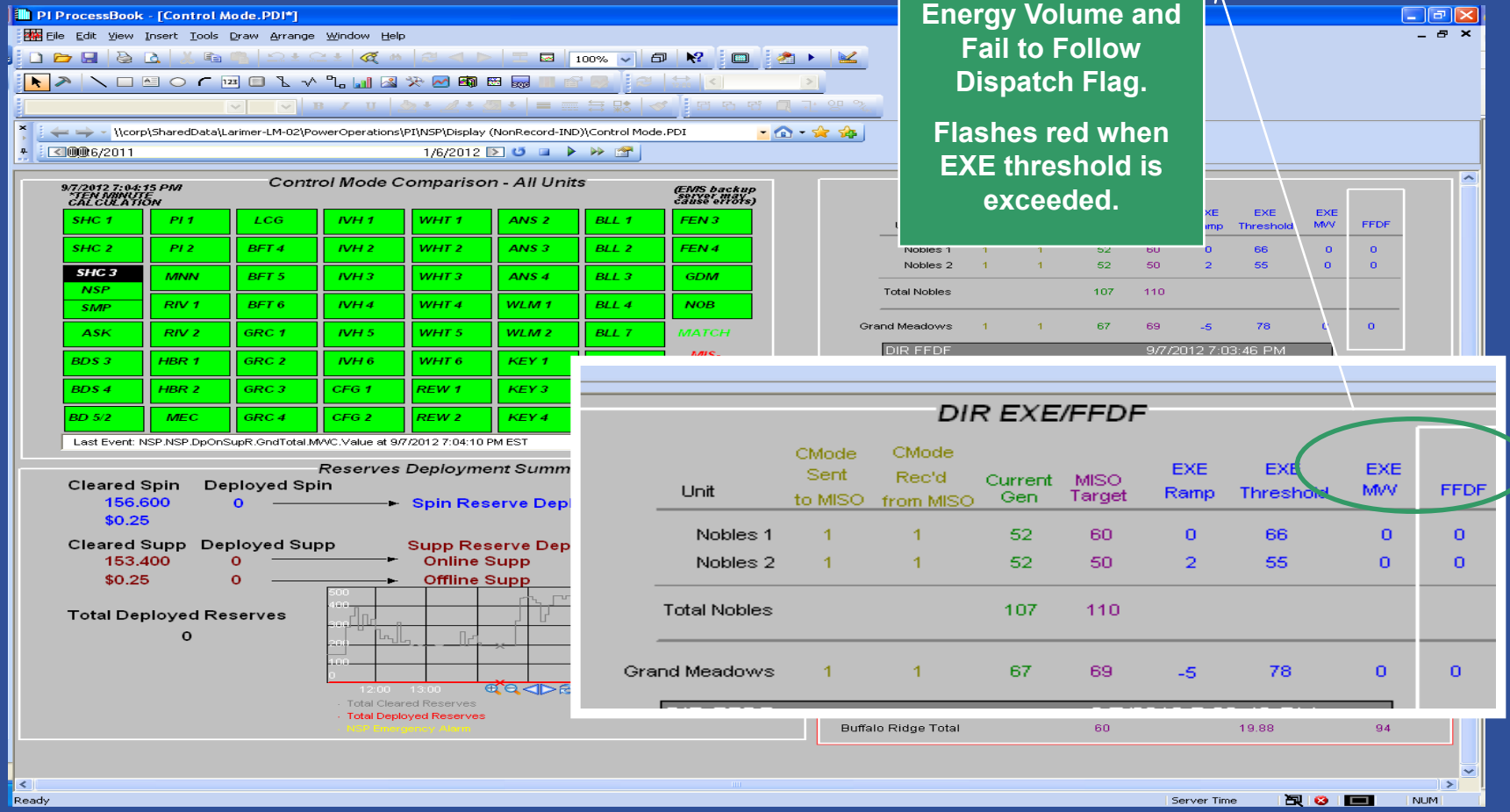
NSP – Excessive Energy at DIR Units

- PROBLEM during ramp events
  - DIR Wind locations received Failure to Follow Dispatch Flags (FFDF)
  - Excessive generation (EXE) is output exceeding 108% of dispatch target for 4 consecutive 5-minute intervals within an hour
    - Occurs during wind ramps when park potential is quickly increasing
  - EXE is paid lesser of LMP or unit offer price
    - NSP offer price is negative for farms receiving a Production Tax Credit (PTC)
    - Therefore NSP received a charge--rather than a payment--for the portion of the output that exceeded the EXE threshold

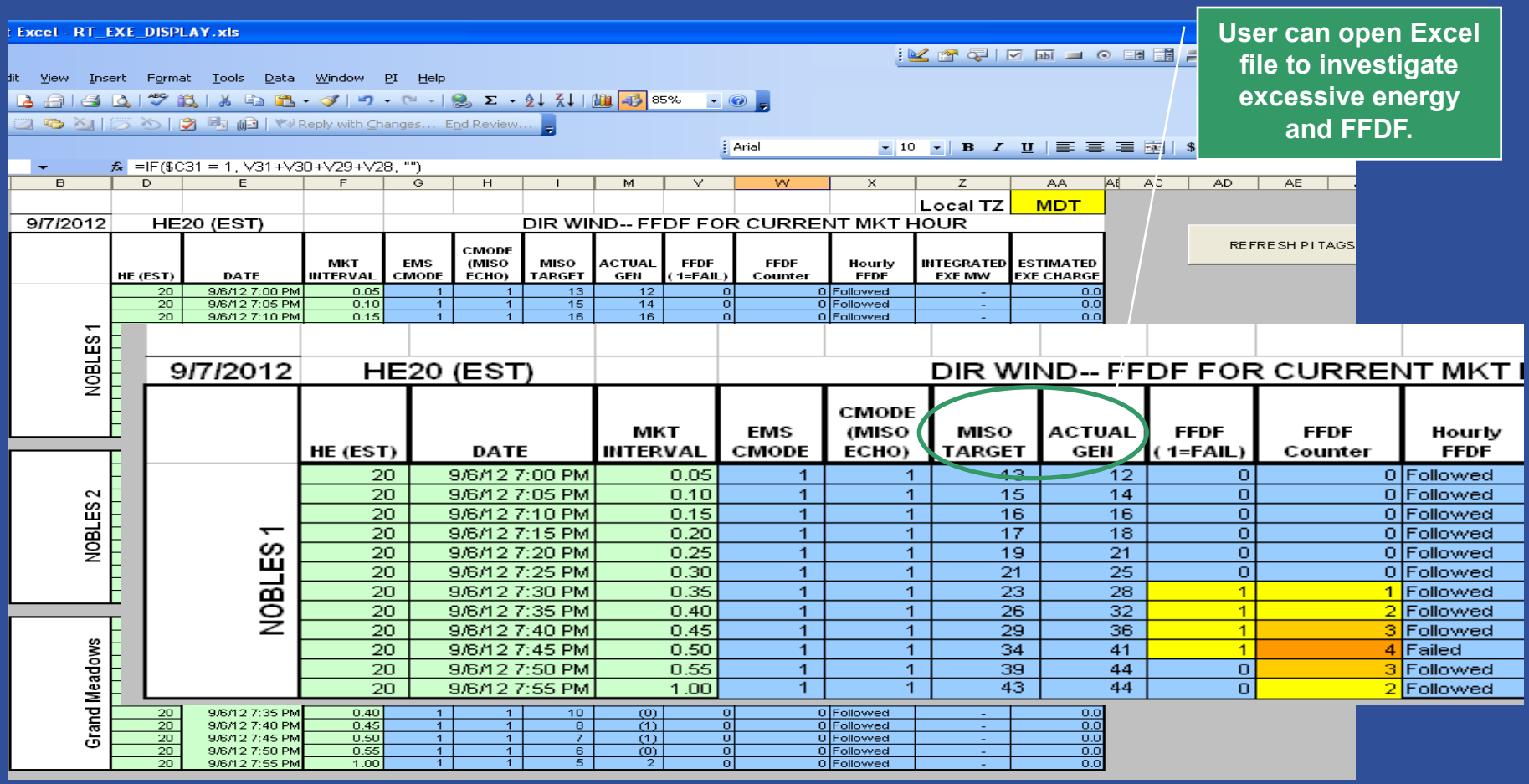
NSP - EXE Charges on DIR Units - Solution

- SOLUTION
  - Build displays to provide awareness when DIR output is exceeding set point
  - Provide five minute forecast override capability in EMS

NSP – DIR Display in Pi Process Book

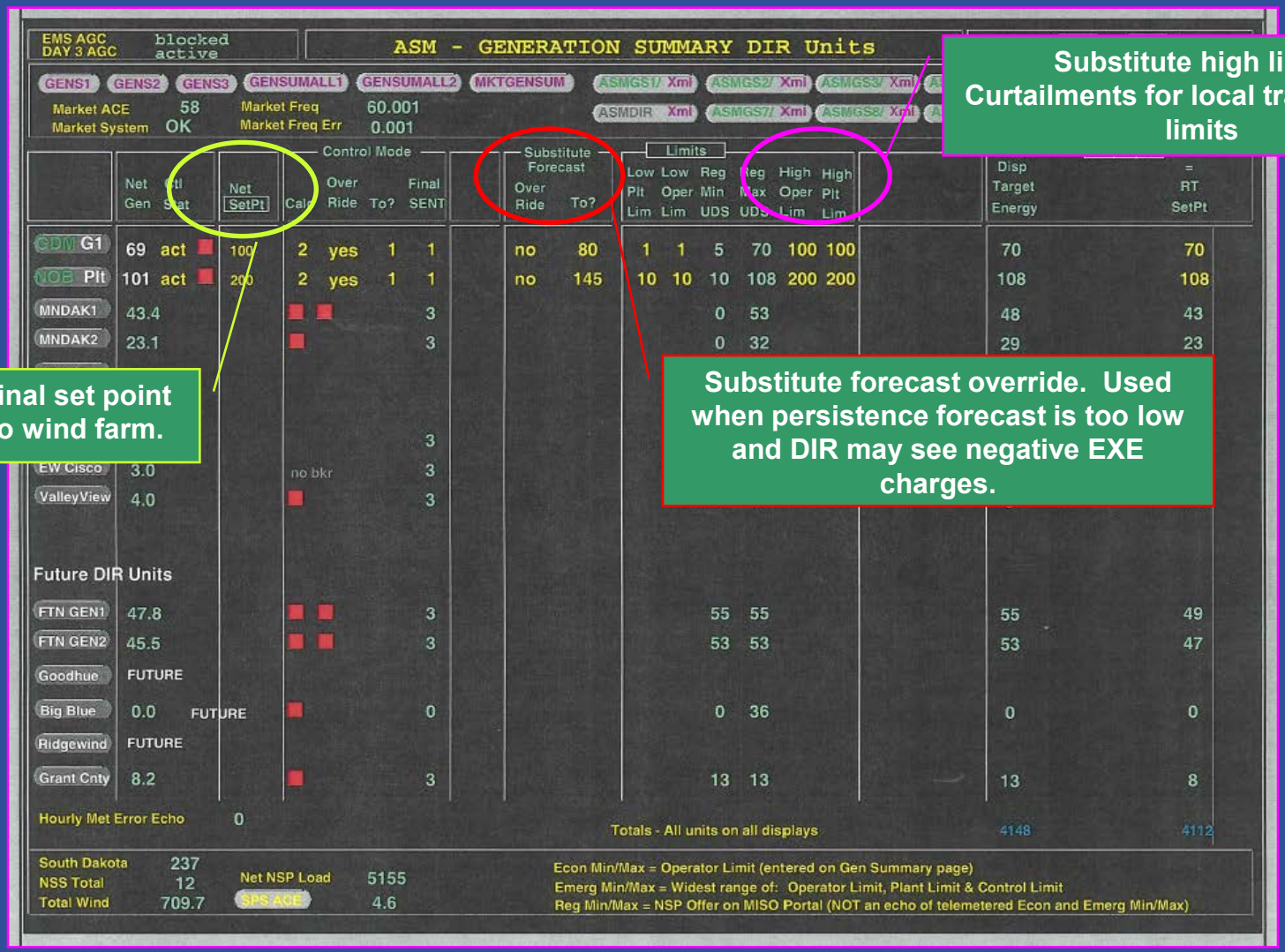


NSP - DIR Display in Excel



User can open Excel file to investigate excessive energy and FFDF.

NSP- EMS Functionality for DIR Units with Set Point Control



Substitute high limits. Curtailments for local transmission limits

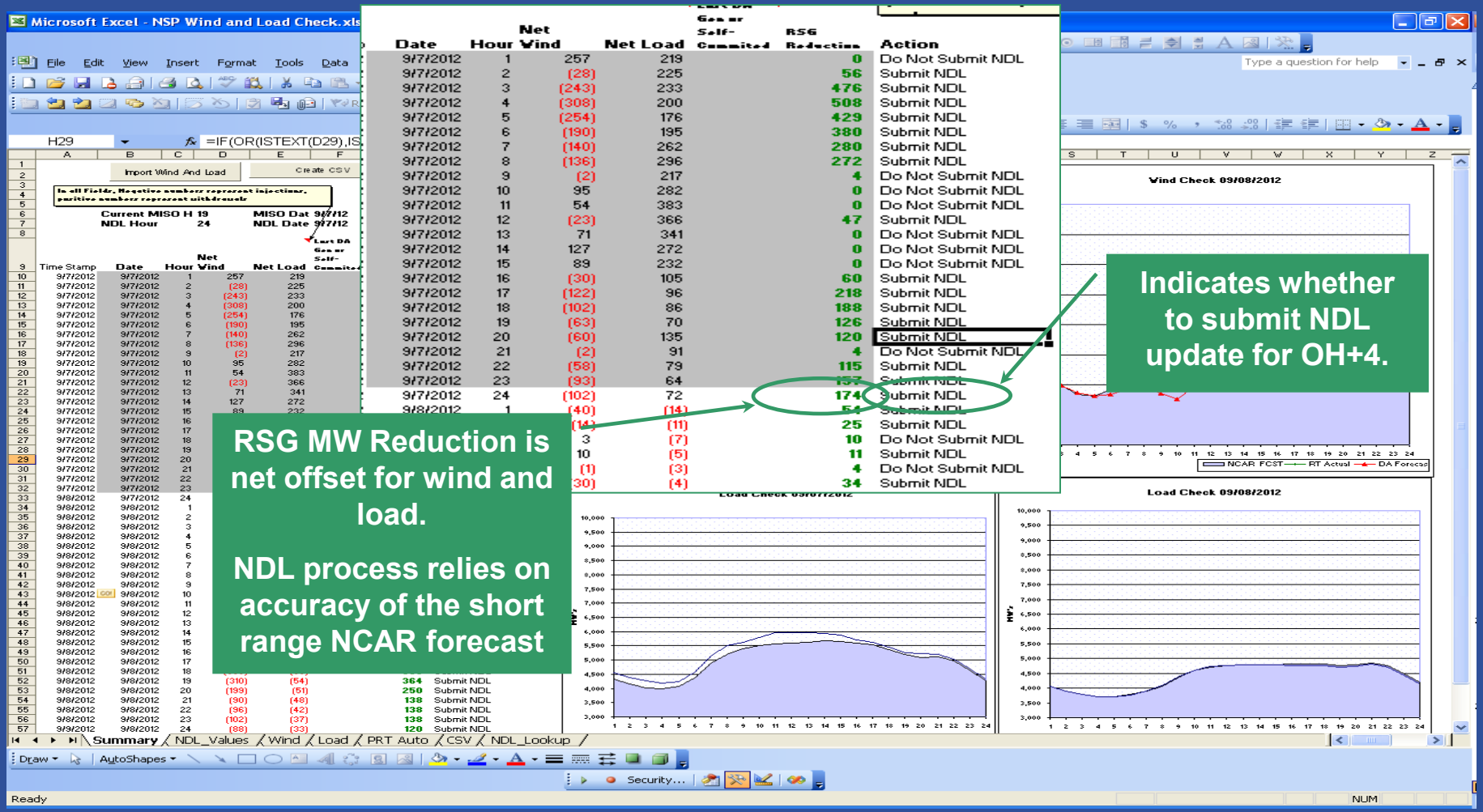
Final set point to wind farm.

Substitute forecast override. Used when persistence forecast is too low and DIR may see negative EXE charges.

NSP – Revenue Sufficiency Guarantee (RSG) charge type

- MISO may commit additional units in real time for reliability purposes
  - These units receive RSG payment to cover production cost
  - Day ahead wind forecast error often the cause of shortages
    - Asset Owner causing the issue funds the payments
- MISO provided Notification Deadline (NDL)
  - OH + 4 is the open market hour for NDL submittal
  - NDL updates are optional
  - Market participants can resubmit forecasts for load and wind
    - Provide a better forecast for intraday reliability run
    - Potentially decrease RSG volume

MISO Notification Deadline (NDL)



Opportunities for Improvement in Displays

- NCAR GUI or ad-hoc displays could
  - Provide confidence interval based on more recent real time performance of NCAR
    - Currently based on 7 day rolling performance
  - Provide probability of particular size wind ramp events occurring at any given time
- Layer NCAR snapshots over maps of wind locations to spot trends at particular wind farms
- Quantify cost savings for wind forecast improvements for wind operating in RTO markets
  - investigate specific market charge types for unexpected consequences

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Questions?